APPENDIX E
RELEASE AND EXPOSURE METHODOLOGY AND DATA

Exhibit E-1. PCE Emissions by Machine Type[a]

Machine Type with Typical Controls	Emissions for a Typical Cleaner (gal/yr)
Transfer	330
Vented	220
Converted	170
Closed-loop	80

[a] Source: CEPA, 1993. These emissions data were used in estimating releases to air in Exhibit 4-1.

**Exhibit E-2. Emission Factors Used to Estimate Releases of Solvent
from Hydrocarbon Dry Cleaning Facilities[a]**

- Dryer - 18 kg VOC is released to air per 100 kg dry weight of articles cleaned based on an average of three studies conducted between 1975 and 1980. The rate of emission is highly dependent on the amount of solvent absorbed and subsequently released during extraction (e.g., loose weaves absorb and release solvents more readily), the efficiency of the extractor, and the size of the dryer load. 3.5 kg VOC is released to air per 100 kg dry weight of articles cleaned with a condenser/solvent recovery dryer.

  The recovery dryer also generates separator water which is discharged to the sewer and received by a POTW. Water enters the solvent bath, through adsorption from the clothes and the air, at a rate of 0.004 - 0.02 gals/lb articles cleaned (USEPA, 1982). This water may be recovered in the recovery dryer separator or in the distillation separator.

- Filter - After draining a diatomaceous earth filter, the filter muck contains approximately 8 kg solvent per 100 kg dry weight of articles cleaned (USEPA, 1982). This average depends on the type of filter used (i.e., the amount of diatomaceous earth required by the filter), and the soil loading of the clothes. When cartridge filters are used, less than 1.0 kg solvent per 100 kg dry weight of articles cleaned is found in the spent filter medium.

- Settling Tanks - No emission factor available. Settling tanks may be used instead of filters for highly contaminated solvent. The solvent content may be from 80 to 200 percent, by weight, of settling tank waste. Settling tank waste may be burned in a boiler, discarded with general drycleaning waste, or sold to a solvent reprocessor. It is generally too contaminated to treat in the vacuum still.

- Vacuum Stills - 1-7 kg solvent per 100 kg dry weight of articles dry cleaned (average of 3 kg solvent) is disposed with the still residue. Solvent is also discharged with the wastewater generated from the still overhead separator, though the quantity is unknown.

- Fugitive Emissions - At least 1 kg of VOC emissions per 100 kg dry weight of articles. This factor is assumed to be the total emissions per 100 kg articles less all other emission factors.

[a] Source: USEPA, 1982.

Exhibit E-3. Environmental Release Estimates of Example Detergent #1 Constituents[a]

	Constituent	Weight Percent[b]	Density[c] (g/cm^3)	Releases to water[d] (kg/site-day)
1	water	54	1	0.195 - 0.631
2A	methyl 2-sulfolaurate, sodium salt	3.75	1	0.013 - 0.044
2B	sodium lauryl isethionate	3.75	1	0.013 - 0.044
3	ethoxylated sorbitan monodecanoate	7.5	1.1	0.027 - 0.088
4	lauryl polyglucose	7.5	1	0.027 - 0.088
5	Aveda's fragrance	1	1	0.004 - 0.012
6	sodium citrate	2.5	1	0.009 - 0.029
7	cellulose gum	5	0.75	0.018 - 0.058
8	acetic acid	5	1.049	0.018 - 0.058
9	citric acid	2.5	1.542	0.009 - 0.029
10	diazolidinyl urea	7.5	1	0.027 - 0.088
	totals	100	1.01	0.360 - 1.169
			Total release minus water	0.165 - 0.538

[a] These release estimates correspond to 29.5 to 95.4 gallons/year total detergent use and release rates (from the Machine Wetcleaning Release Assessment in Section 4.2.2) and are based on assumptions that: example detergent #1 contains the constituents listed for All-Purpose Cleanser (Aveda, 1992) from the Multi-Process Wetcleaning Report (USEPA, 1993); all of the formulation used is released to water; and, a CTSA model facility operates for 312 days/year and the annual estimated release to water is divided equally over the operating days.

[b] Assumed based on assumed function of constituent.

[c] From Chemical Properties and Information tables in Appendix A; if no data available, assumed 1 g/cm^3.

[d] For the risk assessment, these total detergent releases were converted from volume (gallons per day) to weight (kilograms per day [kg/site-day]) using the total formulation density. The total weight was then distributed among the constituents using the weight percents of the constituents.

Exhibit E-4. Environmental Release Estimates of Example Detergent #2 Constituents[a]

	Constituent	Weight Percent[b]	Density[c] (g/cm^3)	Releases to Water[d] (kg/site-day)
1	water	54	1	0.225 - 0.728
2	lauryl polyglucose	4.28	1	0.018 - 0.058
3	lauric acid diethanolamide	4.28	0.979	0.018 - 0.058
4A	methyl 2-sulfolaurate, sodium salt	2.14	1	0.009 - 0.029
4B	sodium lauryl isethionate	2.14	1	0.009 - 0.29
5	sodium laureth sulfate	4.28	1	0.018 - 0.058
6	sodium citrate	2.5	1	0.010 - 0.034
7	cocamidopropyl betaine	4.28	1	0.018 - 0.058
8	Aveda's fragrance (orange)	1	1	0.004 - 0.013
9	cocoamphocarboxyproprionate	4.28	1	0.018 - 0.058
10	sodium carbonate	10	2.53	0.042 - 0.135
11	citric acid	2.5	1.542	0.010 - 0.034
12	diazolidinyl urea	4.28	1	0.018 - 0.058
	totals	100	1.17	0.417 - 1.350
	Total releases minus water			0.192 - 0.622

[a] These release estimates correspond to 29.5 to 95.4 gallons/year total detergent use and release rates (from the Machine Wetcleaning Release Assessment in Section 4.2.2) and are based on assumptions that: example detergent #2 contains the constituents listed for Fabric Cleanser (Aveda, 1992) from the Multi-Process Wetcleaning Report (USEPA, 1993); all of the formulation used is released to water; and, a CTSA model facility operates for 312 days/year and the annual estimated release to water is divided equally over the operating days.
[b] Assumed based on assumed function of constituent.
[c] From Chemical Properties and Information tables in Appendix A; if no data available, assumed 1 g/cm^3.
[d] For the risk assessment, these total detergent releases were converted from volume (gallons per day) to weight (kilograms per day [kg/site-day]) using the total formulation density. The total weight was then distributed among the constituents using the weight percents of the constituents.

Summary of Dry Cleaning Worker Population and Subpopulation

Exhibits E-5, E-6, and E-7 contain data and assumptions used to estimate the numbers of workers in perchloroethylene and hydrocarbon dry cleaning facilities and percentages of these workers by job title. Exhibit E-5 shows the original data that were the bases for final CTSA estimates of numbers of workers. This exhibit also shows the calculation of estimated number of drop-off/ pick-up sites.

Exhibit E-5. Summary of American Business Information (ABI) 1994 Dry Cleaning Worker Population Data[a,b]

Size Category (number of shop workers)	Number of Shops	% Age of all Shops	Fraction of Known Shops	Minimum Workers	Maximum Workers
1 to 4	33,853	70	0.72	33,853	135,412
5 to 9	8,252	17	0.18	41,260	74,268
10 to 19	3,482	7	0.07	34,820	66,158
20 to 49	1,095	2	0.02	21,900	53,655
50 to 99	175	0.4	0.004	8,750	17,325
100 to 249	62	0.1	0.001	6,200	15,438
250 to 499	6	0.01	0.0001	1,500	2,994
500 to 999	1	0.002	0.00002	500	999
unknown	1,161	2	NA	1,161	1,161
Totals	48,087	100	1	149,944	367,410

[a] Source: ABI (1994) as cited in NIOSH (1997).

Exhibit E-6. Summary of Estimated Dry Cleaning Worker Population Data[a]

Size Category (number of shop workers)	Number of Shops	Percent of all Shops	Minimum Workers		Maximum Workers
1 to 4	22,604	63	22,604		90,414
5 to 9	8,456	23	42,281		76,105
10 to 19	3,568	10	35,681		67,795
20 to 49	1,122	3	22,442		54,982
50 to 99	179	0.5	8,966		17,754
100 to 249	64	0.2	6,353		15,820
250 to 499	6	0.02	1,537		3,068
500 to 999	1	0.003	512		1,024
	Number of Shops	**Percent of all Shops**	**Minimum Workers**	**Midpoint Workers**	**Maximum Workers**
Revised Total	36,000	100	140,377	233,670	326,962
Allotted to PCE (85% PCE)	30,600		119,320	198,619	277,918
Allotted to HC (15% HC)	5,400		21,057	35,050	49,044
Average number of employees per site			3.9	6.5	9.1

[a] For the CTSA, the ABI data from Exhibit E-4 were adjusted: (1) to exclude drop-off/pick-up (DO/PU) sites; (2) to proportionally distribute the 1,161 shops in "unknown" size category above into the known size categories. DO/PU sites were assumed to be the difference between the total number of shops (48,087) from Exhibit E-4 and the total number of shops (36,000) estimated for the CTSA to perform drycleaning. Therefore, 12,087 sites are estimated to be DO/PU sites. DO/PU sites are all assumed to be in the 1-4 size category. Adjustment (1) was then accomplished by subtracting the 12,087 DO/PU sites from the 33,853 shops in the 1-4 size category. Adjustment (2) was accomplished for each size category by adding to the number of shops for that category the product of 1,161 times the fraction of known shops for the category. The results of these adjustments are in Exhibit E-5. The numbers of workers from this exhibit were rounded before being reported in the text (Section 4.4.1 for PCE and Section 4.4.2 for HC).

Exhibit E-7. Dry Cleaning Worker Subpopulation Estimation[a,b]

Job Title	Estimated Number of Workers	Percent of all Workers[c]
Mgr/Admin	1,655	3.8
Bookkeeper	208	0.5
Clerk	8,068	18.5
Foreman	84	0.2
Installer	86	0.2
Engineers	23	0.1
Tailors	4,306	9.9
Presser	6,759	15.5
Seamstress	246	0.6
Operator	21,240	48.7
Sewer	296	0.7
Driver	644	1.5
PEI Total	43,615	100

[a] Source: PEI, 1985.
[b] Exhibit E-6 shows the data used to estimate percentages of dry cleaning workers by job title. The percentages of workers for the job titles from this exhibit were reported in Section 4.4.1 for PCE and Section 4.4.2 for HC.
[c] Note: 3.6 is the percent of workers other than those titled manager, operator, presser, tailor, and clerk.

**Exhibit E-8. Determination of Estimated Dermal Exposure Durations
for Potential Liquid PCE Contact[a]**

Activities	Avg. Frequency, Duration
1. loading/ unloading machine (transfer machines)	6/day (CTSA), 2 min/event (NIOSH)
2. waterproofing (not all shops)	1-2/day (assumed*), 2 min/event (NIOSH)
3. changing filters	demand (NIOSH); 5 min/event (NIOSH)
4. cleaning still	1/day (NIOSH); 5 min/event (NIOSH)
5. emptying button trap	1/day (NIOSH); < 1 min/event (assumed*)
6. filling storage tank	demand (NIOSH); < 1 min/event (assumed*)
7. changing rag filter (not all shops)	1/week (IFI); < 1 min/event (assumed*)
8. cleaning muck cooker (powder filters only)	assume same as still cleaning

Assumptions: Assumed* in above list indicates no source of estimate was found, and the value was based on an assumption of the amount of time to complete the activity. Operators are primary workers who perform the above activities which have potential for liquid PCE contact. For each transfer contact, add two minutes to account for time prior to total PCE evaporation; for each non-transfer contact, add 1 minute.

Summation (estimated total time of contact plus post-contact evaporation of liquid PCE)

Transfer machine operators:	6x4+5+2 = 31 min/day daily routine
Dry-to-dry operators:	5+2 = 7 min/day daily routine
Non-routine add-ons:	5-6 min/week = 1 min/day avg. assumed
Transfer operators:	< 32 min/day total (routine plus non-routine)
Dry-to-dry operators:	< 8 min/day total

[a]Source: NIOSH, 1997; IFI, 1994.

Exhibit E-9. Exposure Assessment Methodology- Background on Worker Exposure

The USEPA/OPPT/Chemical Engineering Branch (CEB) standard methods and procedures for assessing worker exposure were used for this CTSA and are presented in *Preparation of Engineering Assessment, Volume I: CEB Engineering Manual* (USEPA, 1991). For many worker exposure assessments, data are unavailable or incomplete, and screening-level methods must be used. Screening-level assessments rely on the use of readily available information and data and are generally considered to be conservative (protective) in nature. However, screening-level estimates are often quite uncertain and may over- or under-estimate exposures by one or more orders of magnitude.

Key elements of the worker exposure assessment include, for a given worker population, such as perchloroethylene process operator: the number of workers in that population; routes of exposure; measures of amounts of exposure to a chemical or set of chemicals, such as potential dose rates (PDRs)(e.g., milligrams per day [mg/day]), or the amounts of chemicals to which a worker may be exposed over a given period of time via a given route) , or, alternately, exposure concentrations (ECs)(e.g., parts per million (ppm) time-weighted average [TWA]), which may be translated to PDRs; and, the frequency of exposure (e.g., days/yr) for each dose rate. The following paragraphs briefly describe the assessment methods.

The National Occupational Exposure Survey (NOES) database is frequently used to estimate the number of workers potentially exposed to substances during industrial and commercial operations. The survey was conducted in 1980 - 1983 and information was extrapolated to make national estimates of numbers of workers potentially exposed and numbers of facilities where the substance is present. Because of the age of the data, the survey itself, and the extrapolation to national averages, there are several uncertainties associated with the data. NOES estimates are fairly uncertain estimates . The NOES survey data were not used to estimate the numbers of workers for established cleaning processes because a number of other data sources indicated that the NOES data were extremely inaccurate for this industry. Data documented in other sources were used to estimate the number of workers per site because those sources were expected to be more up-to-date and accurate than the NOES data.

There are two primary routes of worker exposure assessed in this CTSA. Inhalation exposure, or workers breathing workplace air containing significant concentrations of volatile solvents, is expected to be the most significant route for solvents used in dry cleaning. Dermal exposure, or workers getting solvent and detergents on the skin during various work activities, is expected to be the significant route of exposure for non-volatile chemicals, such as most detergent components. Dermal exposure is also a route of worker exposure for solvents. Ingestion may be a route of exposure for workers who may, for example, eat food contaminated with cleaning chemicals from the workers' hands. However, no data or estimation method is known to make an estimation of worker exposure via this route, and this route would be generally expected to be a much less significant route relative to the inhalation and dermal routes.

When assessing the amounts of chemicals to which workers are exposed, an order of preference of data or methods is used. The first preference is personal monitoring data on chemical being assessed for the population being assessed, and this type of data was available for the worker inhalation exposures assessed in the Cleaner Technologies Substitutes Assessment. Given that monitoring data was not available for worker dermal exposures, modeling was used. The models used are based on some limited studies conducted on retention of liquids.

Exhibit E-10. Worker Exposure - Inhalation

Regarding worker inhalation exposures, several monitoring data sets were found for airborne solvent exposure concentrations (ECs) in dry cleaning facilities. Only personal (not area, bulk or other) samples were included and short-duration (< 1 hour) measurements were not included in the CTSA. To include non-detect (i.e., zero) measurements in the mean EC estimates based on OSHA OCIS data, non-detects were assigned the value of the detection limits (DLs) divided by the square root of 2 (reflecting that these data sets appear to be skewed) (OCIS, 1994, 1998). However, DLs were not provided with these data sets. Therefore, the lowest measured value in each data set was assumed to be slightly higher than the DL for that set, resulting in the following assumed DLs: 0.01 ppm for PCE, 5 mg/m^3 for Stoddard solvent. All inhalation ECs to solvent vapors (PCE and HC processes) may be converted to potential dose rates (PDRs) based on the assumption that workers may be exposed to the measured time-weighted average (TWA) concentrations of the solvent for eight hr/day and that the workers have an average breathing rate of 1.25 m^3/hr. It should be noted that a number of the monitored data points are less than 8-hour TWAs, but it was assumed that these observed TWA were the same as an 8-hour TWA.

Example calculation for inhalation EC conversion is presented below.

Inhalation Exposure

For EC units conversion from ppm to mg/m^3, we use the ideal gas law. The general equation is

ppm (PCE in air) x MW PCE x 1,000 mg/g / Vmol x 1,000 L/m^3 = mg/m^3 (PCE in air)

where

ppm = g-mol PCE per 1,000,000 g-mol air;
MW = molecular weight of PCE in g/g-mol (165.8);
Vmol = molar volume at ambient conditions (1 atmosphere and 25°C) (24.45).

The general equation reduces to ppm x MW / Vmol = mg/m^3. For example, the exposure concentration for workers in facilities using transfer machines before 1/1/87 from Exhibit 4-6 is 55.3 ppm. The following calculation shows the conversion:

55.3 ppm PCE x (165.8/24.45) mg/m^3/ppm

= 375 mg/m^3 PCE.

Exhibit E-11. Worker Exposure - Dermal

Dermal PDRs to solvents and detergents were estimated using standard assumptions, as described in *Preparation of Engineering Assessment, Volume I: CEB Engineering Manual* (USEPA, 1991). Dermal PDRs are presented as bounding estimates based on limited data and engineering judgment. These estimates assume: 1 contact per day for low-volatility chemicals and that workers wash up at meal times and/or end of the shift; contact or immersion of 1 or 2 hands depending on the activity; no use of protective clothing, such as gloves, or other controls to mitigate exposure. For a given worker activity, this method assumes a specific surface area contacted by chemical and a specific surface density of that chemical to estimate a PDR. Only one contact per day is assumed for low-volatility chemicals because the surface density for those chemicals is not expected to be significantly affected either by wiping excess from skin or by repeated contact(s) with additional chemical; i.e., wiping does not remove a significant fraction of the small layer of chemical adhering to the skin, and additional contacts with the chemical do not add a significant fraction to the layer of chemical on the skin.

Example calculation for dermal PDR estimations is presented below.

Dermal Exposure

Potential dose rates for occupational dermal exposure to PCE on pages 4-21 and 4-22 are based upon OPPT's Occupational Dermal Exposure Model and are calculated as follows:

(1)   Article transfer from washer to dryer: 1300 cm^2 (skin area exposed) x 14mg solvent/cm^2/contact x 1 mg PCE/mg solvent = 18,000 mg/contact

(2)   Other Activities: 1300 cm^2 x 3 mg solvent/cm^2/contact x 1 mg PCE/mg solvent = 3,900 mg/contact

For wet cleaning detergent components, the above potential dose rates estimated for PCE are simply assumed to be the same for the detergent formulation multiplied by 1 contact per day (this assumption is discussed above) and the weight fraction of the component in the formulation (or diluted formulation). An example using "constituent Z" of the detergent formulation is as follows:

3,900 mg detergent/contact x 1 contact/day x 0.5 mg constituent Z/mg detergent = 2,000 mg constituent Z/day

Exhibit E-12. Exposure Assessment Methodology - Non Worker Populations

Exposures to non-worker populations were estimated using Agency guidance published in the Federal Register (USEPA, 1992).   Exposure estimates were developed based on available data from monitoring studies as well as exposure models. Monitoring data were used wherever possible. Inhalation, dermal, and ingestion exposures to PCE were estimated for various exposed populations. These populations include co-located residents, children, the elderly, persons wearing dry cleaned clothing, and persons exposed to ambient levels of PCE.

Much less information was available for use in assessing hydrocarbon exposures. In this case, a model was used to estimate chronic exposures received by members of the general public. In the case of machine wet cleaning (MWC) chemicals, there were no human health concerns. However, in this case releases to surface water were used to estimate predicted environmental concentrations in water.

The equations used to estimate human exposures are shown below:

(1)   Inhalation Exposure

Inhalation exposures to non-worker populations are expressed as potential doses in the form of LADCs (for PCE) or ADCs (for hydrocarbons).

(1)   LADC or ADC (mg/m^3) =   [C (mg/m^3) x ED (days)]/ [AT (days)]

where   C   =   Chemical concentration
        ED   =   Exposure duration
        AT   =   Averaging time (for LADC: number of days per lifetime, 25550 days; for ADC, one day)

(2)   Ingestion Exposure

Exposure to clothes cleaning chemicals via ingestion of contaminated drinking water is presented, where relevant, as a potential dose rate expressed as a Lifetime Average Daily Dose (LADD).   LADDs are averaged over a person's lifetime. The equation for drinking water ingestion is as follows:

(2)   LADD (mg/kg/day) = [C (µg/L) x 0.001 µg/mg x Am (L/day) x ED (days)] /   BW (kg) x AT (days)

where   C   = Chemical concentration (µg/L)
        Am   = Amount of water ingested per day; 2 Liters
        BW   = Body weight
        ED   = Exposure Duration
        AT   = Averaging Time; 70 years

Exhibit E-13. Estimates of Workers' Dermal Exposures to Example Detergent #1 Constituents[a]

	Constituent	Weight Percent[b]	Contacting Dilute Formulation via Wet Clothes Transfer[c] (mg/day)	Contacting Full-Strength Formulation (mg/day)
1	water	54	18,000	2,100
2A	methyl 2-sulfolaurate, sodium salt	3.75	0.05	150
2B	sodium lauryl isethionate	3.75	0.05	150
3	ethoxylated sorbitan monodecanoate	7.5	0.10	290
4	lauryl polyglucose	7.5	0.10	290
5	Aveda's fragrance	1	0.01	39
6	sodium citrate	2.5	0.03	98
7	cellulose gum	5	0.06	195
8	acetic acid	5	0.06	195
9	citric acid	2.5	0.03	98
10	diazolidinyl urea	7.5	0.10	290

[a] These estimated dermal PDRs correspond to the estimates presented in section 4.4.3.1 and are based on assumption that example detergent #1 contains the constituents listed for All-Purpose Cleanser from the Multi-Process Wet Cleaning Report (USEPA, 1993).
[b] Assumed based on assumed function of constituent.
[c] Detergent weight fraction of 0.00007 in rinse water based on 150 mL detergent per 20 lb clothes, wash and rinse volumes of 1.35 L water per lb clothes, 5% of wash water remaining in clothes after extraction.

Exhibit E-14. Estimates of Workers' Dermal Exposures to Example Detergent #2 Constituents[a]

	Constituent	Weight Percent[b]	Contacting Dilute Formulation via Wet Clothes Transfer[c] (mg/day)	Contacting Full Strength Formulation (mg/day)
1	water	54	18,000	2,100
2	lauryl polyglucose	4.28	0.05	170
3	lauric acid diethanolamide	4.28	0.05	170
4A	methyl 2-sulfolaurate, sodium salt	2.14	0.03	83
4B	sodium lauryl isethionate	2.14	0.03	83
5	sodium laureth sulfate	4.28	0.05	170
6	sodium citrate	2.5	0.03	98
7	cocamidopropyl betaine	4.28	0.05	170
8	Aveda's fragrance (orange)	1	0.01	39
9	cocoamphocarboxyproprionate	4.28	0.05	170
10	sodium carbonate	10	0.13	390
11	citric acid	2.5	0.03	98
12	diazolidinyl urea	4.28	0.05	170

[a] These estimated dermal PDRs correspond to the estimates presented in section 4.4.3.1 and are based on assumption that example detergent #2 contains the constituents listed for 100% Fabric Cleanser from the Multi-Process Wet Cleaning Report (USEPA, 1993).
[b] Assumed based on assumed function of constituent.
[c] Detergent weight fraction of 0.00007 in rinse water based on 150 mL detergent per 20 lb clothes, wash and rinse volumes of 1.35 L water per lb clothes, 5% of wash water remaining in clothes after extraction.

**Exhibit E-15. Exposure to Co-located Residents: Information on Monitoring Studies -
Capital District Survey (Schreiber et al., 1993)**

Background: The Capital District Survey was undertaken by the New York State Department of Health in the summer of 1990 to determine if elevated PCE concentrations were present in residences above dry cleaners. When the 102 dry cleaners in Capital District, New York (this is the area around Albany) were surveyed, it was found that 6% (six facilities) used PCE on the premises and were located below occupied apartments (Schreiber et al., 1993). Measurements of PCE concentrations were taken in the room in each building "most likely to have the highest PCE levels" (Schreiber et al., 1993).

Methodology: Dry cleaning facilities were located through the telephone book. The Capital District Yellow Pages listed 102 dry cleaners. Sixty-seven of these facilities cleaned or pressed clothing in the facility. Fourteen drycleaners were located in residential buildings with a total of twenty apartments above them. However, in some of these buildings the apartments were empty or were only used for storage. In two other cases, dry cleaning using PCE did not occur on the premises. This left a total of six co-located drycleaners that used PCE.

In each of these six buildings, the rooms were surveyed to determine where the highest concentrations of PCE were likely to be found. These determinations were made based on location of pathways through which PCE emissions could travel from the drycleaners to the apartments, and the locations of PCE odors in the apartments, if any.

PCE concentration samples were taken during the day (A.M. concentrations, 7:00 A.M. to 7:00 P.M.) and in the evening (P.M. concentrations, taken between 7:00 P.M. and 7:00 A.M.). Sampling in the six control homes was done at the same time. Each control home was located at least 100 meters from one of the six dry cleaning facilities and they were chosen based on their similarity to the study homes. Stainless steel evacuated canisters were used to collect the samples. Samples were analyzed by gas chromatography/mass spectrometry. The detection limit was 0.0015 mg/m^3.

Results: Concentrations in these six apartments (referred to as ‹study homes’) were compared with measurements taken at the control homes. Average daily PCE concentrations in the study homes ranged from 0.100 to 55.0 mg/m^3. The highest concentrations were measured above an old dry-to-dry unit "in poor operating condition" (Schreiber et al., 1993).

In three of the control homes, average measured concentrations were less than 0.0067 mg/m^3. A resident of one control home worked in a chemical laboratory; measured concentrations in this home ranged from 0.077 to 0.103 mg/m^3. Another control home resident worked in a dry cleaner's; measured concentrations in this home ranged from 0.044 to 0.056 mg/m^3. These persons lived in the two control homes with the highest PCE concentrations. In the sixth control home, measured concentrations ranged from 0.0097 to 0.022 mg/m^3 (Schreiber et al., 1993).

Outdoor PCE concentrations were measured near the study homes and the control homes. The outdoor concentrations near the study homes were almost always lower than concentrations measured inside them. In some instances, outdoor concentrations were one to two orders of magnitude lower. Concentrations outside the study homes ranged from 0.066 to 2.6 mg/m^3. Corresponding concentrations inside the study homes ranged from 0.16 to 55.0 mg/m^3.   The highest PCE concentration outside a control home was 0.021 mg/m^3. Most PCE concentrations outside control homes were less than 0.0067 mg/m^3 (Schreiber et al., 1993).

Uncertainties: Apartment residents were asked not to bring newly dry cleaned items into the home in the week prior to sampling. Most residents complied with this request. However, there may have been some individuals who did not. Measured concentrations for such individuals' residences could be higher than for others. Additionally, because sampling occurred during the summer, residents were not asked to keep their windows closed. In two of the study homes windows were open during the sampling period (Schreiber et al., 1993). This could have lowered measured concentrations by introducing a downward bias.

Exhibit E-16. Exposure to Co-located Residents: Information on Monitoring Studies - Consumers Union (Wallace et al., 1995)

Background: In 1995, Consumers Union published a study of PCE concentrations in 29 apartments above dry-to-dry non-vented machines. These apartments were located in 12 residential apartment buildings, each with one dry cleaner. Measurements were taken from December 1994 to May 1995. Sampling in each apartment occurred over four 24-hour periods, with Sundays included if possible. Results were averaged over the four days of sampling in each apartment. Samples were also taken in control apartments, located at least one block from a dry cleaner (Wallace et al., 1995).

Methodology: Consumers Union identified 12 dry cleaners who used dry-to-dry, nonvented machines. Each cleaner was located in a separate residential building in Brooklyn or Manhattan. Residents of these 12 apartment buildings were asked to participate in the study. In each residential building, Consumers Union attempted to sample in different locations at varying distance from the dry cleaner. Samples were taken in twenty-nine apartments using a passive personal monitor. According to Consumers Union, "Samplers were placed in areas with good air circulation, and usually in heavily used rooms (living room, kitchen, bedroom). If residents said they had smelled solvent odors, the monitors were sited in a room where odors had been smelled, or near a likely entry point for vapors" (Wallace et al., 1995). Samples were analyzed using gas chromatography coupled with electron capture detection, with a carbon disulfide eluent. Samples were also taken in ten control apartments, located at least one block from a dry cleaner.

Results: A total of 116 individual 24-hour samples were taken in co-located apartments. Single-day measured concentrations ranged from 0.0007 mg/m^3 to 38.0 mg/m^3. Four-day average concentrations ranged from 0.007 mg/m^3 to 25.086 mg/m^3. The four-day average concentrations represent the average PCE measured value in each apartment over the four days of sampling. In 83% of the apartments, average concentrations exceeded 0.1 mg/m^3; in 28% of the apartments average concentrations exceeded 1 mg/m^3; in 10% of apartments, average concentrations exceeded 5 mg/m^3. The median value for these four-day average PCE levels in co-located apartments was 0.441 mg/m^3. The mean value was 1.85 mg/m^3. Consumers Union concluded that "more modern dry-cleaning equipment does not adequately protect the health of apartment residents from the risks perc poses" (Wallace et al., 1995).

The highest PCE concentrations were measured above a dry cleaner using a dry-to-dry vented machine that had been modified to function like a non-vented machine. Consumers Union concluded that the machine "had been described as an unvented dry-to-dry machine, but probably did not represent the modern equipment that was our focus" (Wallace et al., 1995). The lowest measured concentrations were measured in apartments at some distance from the dry cleaners, even though they were in the same building. In one case in which measured PCE concentrations were low, the apartment was located "on the far side of a large building from the cleaner, essentially a block away from it" (Wallace et al., 1995).

Concentrations in the control apartments were much lower, ranging from less than 0.0007 mg/m^3 to 0.0305 mg/m^3 for the single-day average values. The overall average PCE concentration, based on values from all control apartments, was 0.006 mg/m^3 (Wallace et al., 1995).

Uncertainties: Residents of the apartments tested volunteered for the study and it is possible that people who thought their apartment was polluted with PCE were more likely to volunteer for the testing. However, Consumers Union concluded that there is nothing about the buildings or cleaners chosen to suggest that they were more likely to find perc problems in the tested buildings than any other.

Testing was limited to one location in each apartment, and testing was limited to only four (usually consecutive) days, which does not provide a complete picture of a resident's exposure over an entire year, or longer. It is not known whether the monitor was placed in the best spot to measure perc exposure in each apartment.   CU commented on possible limitations of its monitor placement and study duration.

Results appear to apply to unvented dry-to-dry equipment, although there are numerous variations in the design and type of machines in this class. It was not possible to differentiate among varieties of modern unvented dry-to-dry equipment.

Finally, the study did not attempt to determine whether additional control strategies (e.g., installation of vapor barriers) could consistently keep perc levels in apartments at or below 0.100 mg/m^3, which Consumers Union chose because it is the New York State Department of Health guideline for non-cancer health effects.

Other Uncertainties: Residents were instructed not to bring any drycleaned clothes into the tested apartment during the sampling periods. It is not stated whether all of the apartment dwellers complied with this request. Additionally, New York City Department of Health (NYCDOH) officials had investigated complaints in six of the 12 drycleaners before the study began, and five of those were inspected several times. However, Consumers Union argued that this is not unusual, because the NYCDOH investigates many facilities each year (for example, 133 facilities were investigated in 1993). Therefore, CU claimed it is not unreasonable that six of the 12 drycleaners were investigated before the study began. Four other dry cleaners were investigated by NYCDOH after the study began; Consumers Union provided residents with a copy of the results, and encouraged them to call the NYCDOH if measured concentrations were above 0.100 mg/m^3.

**Exhibit E-17. Exposure to Co-located Residents: Information on Monitoring Studies -
New York State Health Department Data, Unpublished**

Background: Data on PCE concentrations have been collected in New York State by the New York City and State Departments of Health (NYCSDOH) in response to residential complaints. These data consist mainly of four-hour samples taken during the daytime, although a few sets of twenty-four hour samples are also available.

Methodology: Because these data have not been published by their collectors, they are accompanied by minimal descriptive information. More than fifty samples above 23 machines were taken in New York in response to residential complaints between 1991 and 1993 (NYSDOH, 1993).

Results: PCE concentrations ranged from less than 0.02 mg/m^3 to 2.5 mg/m^3.

Uncertainties: These samples were based on complaints. That means, among other considerations, sampling was not carried out due to machine characteristics, which varied tremendously. Several of the dry cleaners were closed down after these concentrations were measured. They were allowed to reopen after they made improvements to their facilities. Resampling after remediation efforts were made generally showed a decrease in PCE concentrations in co-located apartments.

**Exhibit E-18. Exposure to Co-located Residents: Information on Monitoring Studies -
San Francisco Bay Area (BAAQMD, 1993)**

Background: The Bay Area Air Quality Management District in San Francisco, CA, measured PCE concentrations in the hallways of apartments above four non-vented dry-to-dry machines with refrigerated condensers. These measurements were made to determine if new machines with advanced controls also caused co-located residents to be exposed to high levels of PCE.

Three of the four drycleaners had taken other precautions to minimize fugitive emissions. Two of the dry cleaners had isolation rooms with fans. Emissions were vented into these isolation rooms, which enclose the back of the machines. The fans vent to a stack which exhausts the emissions 10 feet above the building, which minimizes PCE concentrations in the neighborhood.

The other dry cleaner had "a double layer of gypsum board on the ceiling with all joints sealed with aluminized tape to minimize diffusion" (BAAQMD, 1993). The room also contained a window fan.

Methodology: Four buildings were chosen for analysis. Each building contained a new dry-to-dry non-vented machine which had been installed fewer than two years prior to the study. The dry cleaners were located in residential buildings. Two concurrent samples in each building were taken during consecutive drying cycles, which lasted for about 40 minutes. Samples were taken using evacuated stainless steel canisters and analyzed using gas chromatography. No comparison values were taken in unexposed residences (BAAQMD, 1993). These samples were taken over two 40-minute periods; the arithmetic mean was reported (BAAQMD, 1993). PCE concentrations were also measured in the corresponding dry cleaning shops.

Results: PCE concentrations ranged from 0.00224 mg/m^3 to 0.673 mg/m^3. The highest PCE concentrations was taken above a drycleaner that was the subject of a prior PCE odor complaint. This facility did not have room enclosures or fans. Its ventilation was effected by opening the windows and doors (BAAQMD, 1993).

Uncertainties: This study is based on a small sample size, and sampling occurred over a limited duration. In estimating exposure to co-located residents, the assumption is made that PCE concentrations measured in hallways could represent actual exposures to co-located residents. Because these cleaners were selected subjectively from new dry-to-dry machine facilities including one that had already been the subject of an odor complaint, it is not clear whether the group reflects likely exposure levels for properly installed and operating machinery.

**Exhibit E-19. Exposure to Co-located Residents: Information on Monitoring Studies -
Concentrations Measured in Germany and Netherlands
(Fast, 1993; USEPA, 1992; Staub et al., 1992)**

Additional data are available on PCE concentrations in residences above drycleaners in Germany and the Netherlands. Unlike the US data, which appear to show that PCE concentrations are lower above non-vented dry-to-dry machines than above transfer and vented dry-to-dry machines, the European data show no difference in PCE concentrations above vented and non-vented dry-to-dry machines. (Transfer machines are not used in Europe.) Concentrations measured in Baden-Wurttemberg, Germany, ranged from less than one mg/m^3 to 130 mg/m^3, with more than 70% of the measured values less than 5 mg/m^3. The median concentrations measured in co-located apartments in Amsterdam was from 2.2 mg/m^3; the 90th percentile concentration was 17.8 mg/m3, and the maximum measured concentration was 29.9 mg/m^3. These data were not used in this assessment, which is limited to assessing exposures in the United States.

Exhibit E-20. Inhalation Exposure From a Hypothetical Hydrocarbon Facility

Releases to air result from evaporation of chemicals during the drycleaning process. Hydrocarbon vapors released from dry cleaning facilities are then carried by and mixed with outside air. The resulting air concentration will depend on weather conditions. Stagnant conditions will not move vapors away quickly, so local concentrations of the chemical will be higher than the concentrations farther from the plant. Under windy conditions, the vapors will be carried away faster, reducing the local concentrations. The number of people may increase or decrease with distance from the facility.

For our model facility, we assume a building height of three meters, and a width of 10 meters. This is a building approximately the size of a one-car garage. We then pick sample weather conditions to determine what the air concentration of a chemical will be at a set distance from the printing facility. Los Angeles is used because the weather conditions there will result in the highest average concentrations around the facility of any of the approximately 500 weather stations in the United States. The average concentrations around Los Angeles are within an order of magnitude (power of ten) of concentrations expected anywhere else in the country.   If the Los Angeles average concentration were estimated as 10 $\mu g/m^3$, then the average concentration anywhere in the country would be greater than 1 $\mu g/m^3$.

The model used is called Industrial Source Complex Long Term (ISCLT). It was developed as a regulatory model by USEPA's Office of Air and Radiation. The Office of Pollution Prevention and Toxics uses an implementation of ISCLT in the Graphical Exposure Modeling System (GEMS).   Except for items identified, the parameters entered are the regulatory defaults.

In order to obtain the concentration at 100 meters, a special polar grid was entered. The ring distances specified were 100 meters, 200 meters, 300 meters, 400 meters, 500 meters, 600 meters, 700 meters, 800 meters, 900 meters and a kilometer. The air dispersion model calculates the average air concentrations of the chemical vapors in the specified sectors. The sectors are defined by the rings and the compass points, forming an arc-shaped area. There were three calculations per sector.   The compass point with the highest concentration at 100 meters was then used to determine exposure. The location was at 90°, that is, east.

The following table, shows the conversion of air releases from kg/site/day to $g/m^2/s$.

Conversion of Air Releases

Variable	Transfer Machine With Conventional Dryer	With Recovery Dryer	Dry-to-Dry Machine
Release in kg/site/day	17.8	6.6	1.9
Days/year	312	312	312
Release in kg/site/year	5,554	2,059	593
Release in g/site/second	0.18	0.07	0.02

From the concentration in the air, the amount with which an individual may actually come in contact can be calculated by knowing the breathing rate. A moderately active adult breathes 20 m^3 per day. The formula for an annual dose is:

Annual Dose = Concentration x Daily Inhalation Rate x Days per year

where the concentration is in µg/m^3, and the breathing rate is in cubic meters per day. The potential dose normalized for body mass calculated per day for the entire lifetime, is called the Lifetime Average Daily Dose or LADD (Table 3-3). The formula for this dose rate is:

$$\text{LADD} = \frac{\text{Concentration x Daily Inhalation Rate x 0.001 mg/µg}}{\text{Average Body Weight}}$$

The average body weight used in this assessment is 70 kg (an average adult).   Since there is no ratio for the percentage of days spent breathing air containing evaporated blanket wash chemicals, this calculation assumes that a person will be breathing this concentration every day of their life.

Exhibit E-21. Estimating Concentrations in Surface Water

Aquatic life is exposed to PMN substances that are dissolved or suspended in surface waters including rivers and streams, bays and estuaries, and lakes and ponds. Calculations of concentrations in surface water depend on the nature of the water body. Estimated concentrations in surface water are calculated using the rate of release of the MWC chemicals and the flow rate of the stream into which they are discharged.

For the CTSA, generic releases have been estimated for the use of MWC chemicals in wet cleaning facilities. These estimates do not contain any information on specific sites at which those processes will occur. When releases are expected to occur from an unidentified group of processors or users, the assessor must identify the general industry to which that group belongs. These industries and their flow rates are grouped by Standard Industrial Classification (SIC) code. The SIC code for discharges to Publicly Owned Treatment Works (POTWs) is used in this assessment.

Removal of the PMN substance from water can occur during treatment. Two frequently encountered removal mechanisms are adsorption to sludge and hydrolysis. Others include biodegradation and volatilization.   Exhibit A-3, which shows the estimated removal of MWC chemicals in wastewater treatment is shown on page A-17. To calculate concentrations after discharge under these circumstances, the quantity released after treatment in kilograms per site per day is multiplied by a conversion factor of 1,000 and the result is divided by the stream flow in million liters per day (MLD), as shown below:

$$\text{Stream Concentration} = \frac{\text{Release after treatment in kg/site/day x 1000}}{\text{Streamflow in million liters per day}}$$

To assess the potential impact of MWC chemicals on aquatic life, a conservative streamflow estimated is provided. Because facility sizes vary, there are variations in stream flows, and stream flows vary with time.   In this CTSA, concentrations which occur under low flow conditions in small streams were estimated. Specifically, low flow is the lowest flow that continues for seven consecutive days in ten years. This provides conservative estimates of stream concentrations that are compared with Concern Concentrations. The low flow value used in this assessment was 0.7 million liters per day.

Exhibit E-22. Description of the Storage and Retrieval of U.S. Waterways Parametric Data System (STORET)

A search strategy was implemented to determine if there were any additional information available for perchloroethylene concentrations in groundwater. The search statement consisted of "Perchloroethylene or PCE or tetrachloroethylene" and "concentrations or levels" and groundwater. Dialog, STORET, and the Internet were searched (Schaeffer, 1998).

Information found in STORET (all taken from Schaeffer, 1998):

The Storage and Retrieval of U.S. Waterways Parametric Data System (STORET) is the National repository for water quality information on ambient levels of contaminants in water bodies, sediments, fish, and groundwater. It was decided that the emphasis on this STORET retrieval should be placed on public water supplies. The retrieval was based on the terms: municipal, intake, nonambient, ambient, well and supply. All observations across the continental United States from 1988 to 1998 for the following station types were retrieved:

- <u>Nonambient</u> spring and wells (groundwater) that are municipal water supplies/treatment facilities.

- <u>Ambient</u> springs and wells (groundwater) that are municipal water supplies/treatment facilities.

Data are not available *per se* in STORET for Public Water Supplies (STORET Support). The majority of the data is for monitoring. However, using the appropriate keywords, data for tetrachloroethylene (total) was retrieved from STORET for the period 1988 to present in the Continental United States.

- 266 Stations in Utah   -   318 observations were identified from 1988 to 1994 but quantifiable concentrations of PCE were only found in 2 of the samples (at 4.8 and 5.7 μg/L). The other 316 observations had PCE at or below the detection limits, with a maximum of 2.9 μg/L, a minimum of 0.07 μg/L, and a mean of 0.66 μg/L.

- 56 Stations in Utah and Georgia   -   247 observations were identified from 1988 to 1997, with quantifiable levels of PCE found in 5 samples. These detected samples ranged in concentration from 1.50 μg/L to 8.0 μg/L with a mean of 4.34 μg/L. Of the remaining samples, 13 were at or below detection limits, with a maximum of 0.5 μg/L a min of 0.07 μg/L, and a mean of 0.33 μg/L. The 229 remaining samples were non-detected for PCE.

Information found on the Internet (all from Schaeffer, 1998):

ATSDR Toxicological Profiles (copyright 1997) stated that results from an EPA Groundwater Supply Survey of 945 water supplies from groundwater sources nationwide showed tetrachloroethylene in 79 water supplies. The median concentration of the positive samples was about 0.75 μg/L (0.75 ppb), with a maximum level of 69 μg/L (69 ppb).

Massachusetts Military Reservation, Cape Cod, Mass. (dated March 28, 1997) - The Air Force Center for Environmental Excellence (AFCEE) announced that perchloroethylene (PCE) had been detected at 18 ppb (parts per billion) in a groundwater monitoring well in East Falmouth, MA.   Residential private well sample collection was proceeding. As of March 27, 1997, samples from 76 residences were collected in the area.

City of Los Angeles Water Services (copyright 1996) - The North Hollywood Operable Unit (NHOU) began routine full-time operation of their facility January 1, 1990. The NHOU treats 2000 gpm (gallons per minute) groundwater with typical contaminant levels of 120 μg/L trichloroethylene (TCE) and 5.0 μg/L of PCE. The effluent water has about 2 μg/L of TCE and non detectable levels of PCE.

As discussed in Chapter 4, these data were not used in the exposure assessment, because the source of the PCE contamination is unclear. However, these data further document PCE contamination of groundwater supplies.

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